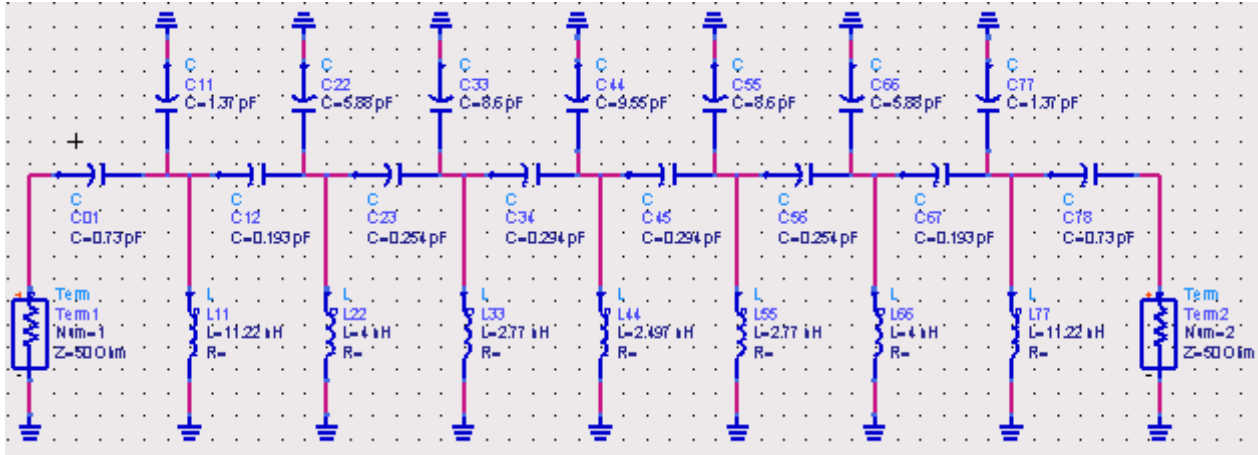


Capacitively Coupled Chebychev BPF

Chris Haji-Michael
www.sunshadow.co.uk/chris.htm



This sheet is used to design a **microwave capacitively coupled BPF**. The maths for this filter is modified from "Theory & Design of Microwave Filters", Ian Hunter, IEE Press.

The schematic designed and simulated is shown above. for N=7, BW=50MHz, 30dB return loss.

The Chebychev plotting part of this sheet was written by Lance Lascari, <http://tools.rfdude.com>

Main user input area:

$$\mu\text{m} := 10^{-6} \cdot \text{m} \quad \text{nH} := 10^{-9} \cdot \text{henry}$$

L_{ar_db} := 30 Passband return loss in dB

N := 7 Order of the filter, this needs to be above 2 and even numbers.

f_{gm} := 1 · GHz **Z₀ := 50 · Ω** **bandwidth := 50 · MHz**

Start Calculating...

$$f_{\text{low}} := f_{\text{gm}} - \frac{\text{bandwidth}}{2} \quad f_{\text{high}} := f_{\text{gm}} + \frac{\text{bandwidth}}{2} \quad \text{bw} := \frac{f_{\text{high}} - f_{\text{low}}}{f_{\text{gm}}}$$

$$f_{\text{bp}}(f) := \frac{1}{\text{bw}} \cdot \left(\frac{f}{f_{\text{gm}}} - \frac{f_{\text{gm}}}{f} \right) \cdot f_{\text{gm}} \quad \text{bwpercent} := \text{bw} \cdot 100 \quad \alpha := \frac{f_{\text{gm}}}{\text{bandwidth}}$$

bwpercent = 5

α = 20

LPF Frequency Response, for Chebychev Polynomials

This section plots the frequency response for the Chebychev BPF

$$Y_o := \frac{1}{Z_o} \quad \varepsilon := \left(10^{\frac{L_{\text{ar_db}}}{10}} - 1 \right)^{-0.5}$$

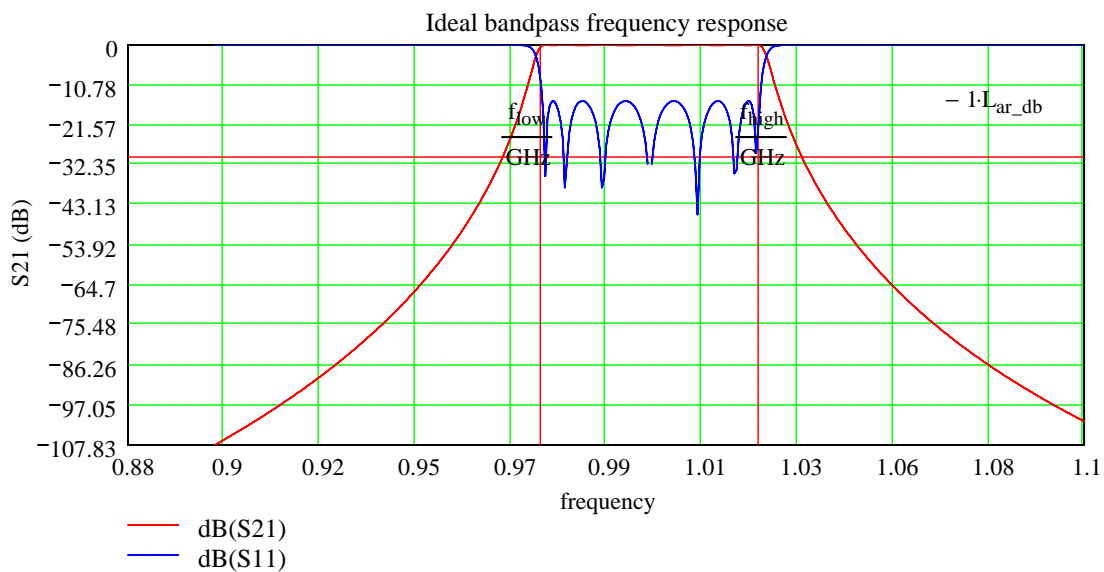
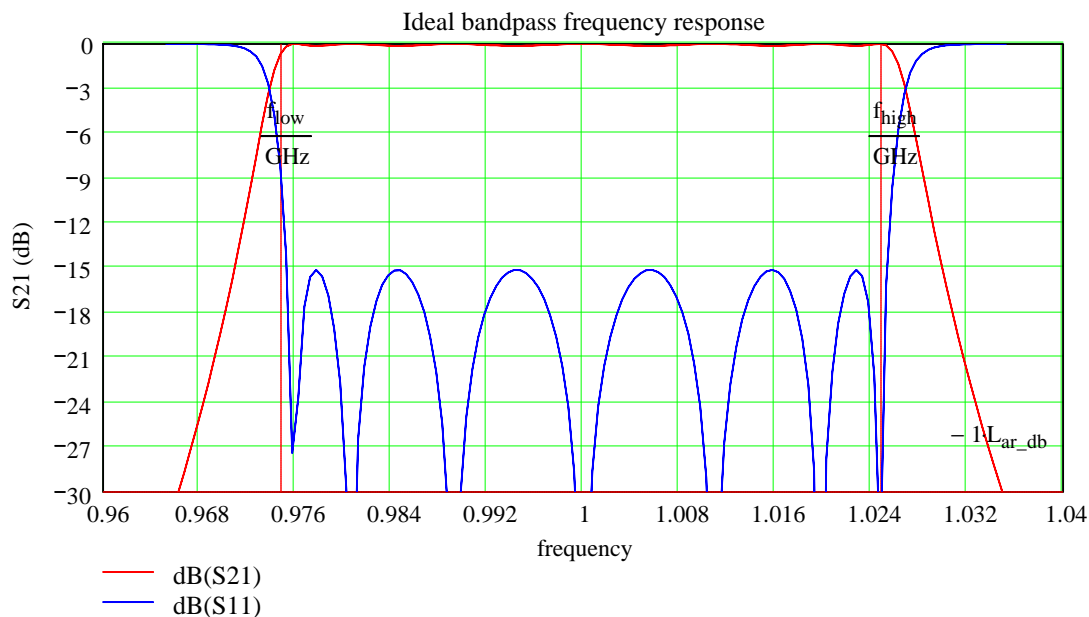
ε = 0.03164

$$L_A(f, f_c) := \begin{cases} 10 \cdot \log \left[1 + \varepsilon \cdot \left(\cos \left(N \cdot \arccos \left(\frac{f}{f_c} \right) \right) \right)^2 \right] & \text{if } f \leq f_c \\ 10 \cdot \log \left[\left[1 + \varepsilon \cdot \left(\cosh \left(N \cdot \operatorname{acosh} \left(\frac{f}{f_c} \right) \right) \right)^2 \right] \right] & \text{if } f > f_c \end{cases}$$

$$S11_A(f, f_1) := 10 \cdot \log \left[1 - 10^{\left(\frac{-L_A(f, f_1)}{10} \right)} \right]$$

$$f_{\text{bp_narrow}} := 0.99 \cdot f_{\text{low}}, \frac{f_{\text{high}} - f_{\text{low}}}{100} + 0.99 \cdot f_{\text{low}} .. 1.01 \cdot f_{\text{high}}$$

$$f_{\text{bp_wide}} := (f_{\text{gm}} - 2 \cdot f_{\text{gm}} \cdot \text{bw}), (f_{\text{gm}} - 2 \cdot f_{\text{gm}} \cdot \text{bw}) + \frac{f_{\text{gm}} \cdot \text{bw}}{100} .. f_{\text{gm}} + (2 \cdot f_{\text{gm}} \cdot \text{bw})$$



Calculate the circuit values.....

$$\eta := \sinh\left(\frac{1}{N} \cdot \operatorname{asinh}\left(\frac{1}{\epsilon}\right)\right) \quad n := 1, 2..N \quad K_{nn, nn+1} := \frac{\left[\eta^2 + \left(\sin\left(\frac{nn \cdot \pi}{N}\right)\right)^2\right]^{0.5}}{\eta}$$

$$nn := 1, 2..N - 1$$

$$nnn := 0, 1..N$$

$$C_n := \frac{2}{\eta} \sin\left[\frac{(2 \cdot n - 1) \cdot \pi}{2 \cdot N}\right]$$

$$\operatorname{Cap}_{0,1} := \frac{1}{\left[2 \cdot \pi \cdot f_{gm} \cdot (\alpha - 1)^{0.5} \cdot Z_o\right]} \quad \operatorname{Cap}_{N,N+1} := \frac{1}{\left[2 \cdot \pi \cdot f_{gm} \cdot (\alpha - 1)^{0.5} \cdot Z_o\right]}$$

Cap_{0,1} = 0.730 pF

$$\operatorname{Ind}_{n,n} := \frac{Z_o}{C_n \cdot 2 \cdot \pi \cdot f_{gm}} \quad \operatorname{Cap}_{nn, nn+1} := \frac{K_{nn, nn+1}}{\alpha \cdot 2 \cdot \pi \cdot f_{gm} \cdot Z_o}$$

$$\operatorname{Cap}_{n,n} := \frac{C_n}{2 \cdot \pi \cdot f_{gm} \cdot Z_o} - \operatorname{Cap}_{n-1,n} - \operatorname{Cap}_{n,n+1}$$

$$\operatorname{Cap}_{1,1} := \frac{C_1}{2 \cdot \pi \cdot f_{gm} \cdot Z_o} - \frac{(\alpha - 1)^{0.5}}{2 \cdot \pi \cdot f_{gm} \cdot Z_o \cdot \alpha} - \operatorname{Cap}_{1,2} \quad \operatorname{Cap}_{N,N} := \operatorname{Cap}_{1,1}$$

C_n =	K_{nn, nn+1} =
0.709	1.216
1.987	1.597
2.871	1.847
3.186	1.847
2.871	1.597
1.987	1.216
0.709	

Cap_{n,n} =	Ind_{n,n} =	Cap_{nnn, nnn+1} =
1.370 pF	11.223 nH	0.730 pF
5.876	4.005	0.193
8.590	2.772	0.254
9.555	2.497	0.294
8.590	2.772	0.294
5.876	4.005	0.254
1.333	11.223	0.193
		0.730

Simulation Results

To test these values I have run a simulation on ADS for $N = 7$, Return Loss = 30dB, $Z_0 = 50\Omega$.

You can see the results are in reasonable agreement. The ripple and return loss (S11) agree are not quite right, but the bandwidth is good.

